Probing the Suhl instability using time resolved X-ray magnetic circular dichroism

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Using X-ray magnetic circular dichroism (XMCD) we directly measure the transverse components of the precessing magnetization in a thin Permalloy films under cw microwave excitation (phase locked to the X-ray flashes). The real and imaginary parts of the rf-magnetic susceptibility are obtained by field sweeps when the phase between exciting rf-magnetic field and the X-ray flashes is adjusted to 0° and 90°, respectively [1]. In addition measurements at different angles between the sample plane and the X-ray beam allow us to determine the in and out-of-plane rf-magnetization components and thereby the ellipticity of the precession. Since the signal is calibrated by XMCD hysteresis loops the dynamic excursion angle of the magnetization can be evaluated. At large microwave fields the susceptibility becomes non-linear due to the decrease of the effective magnetization and the excitation of parametric spin waves (Suhl instability) [2,3]. We measure the precession angle and the ellipticity as a function of rf-power well into the non-linear regime, as can be seen in the figure below. In addition our experiment also allows us to measure the decrease of the time averaged longitudinal component of the magnetization under ferromagnetic resonance [4,5].
By combining the calibrated XMCD measurements of coherent transverse and time averaged longitudinal magnetization components we are able to separate coherent and incoherent components of the magnetic excitation in the non-linear regime. The measurements are performed at various frequencies between 1 and 10 GHz using Permalloy samples with thicknesses of 20, 40, and 80 nm deposited onto SiN membranes. In the experiment we also measure the inductive ferromagnetic resonance signal simultaneously.

Since XMCD also allows for an element specific and therefore layer sensitive investigation of the magnetization dynamics we also investigated exchange coupled magnetic bilayers. Optic and acoustic modes are observed in an interlayer exchange coupled samples and the phase difference between the precessing magnetizations of both layers allows us to determine the coupling energy very accurately [6,7].

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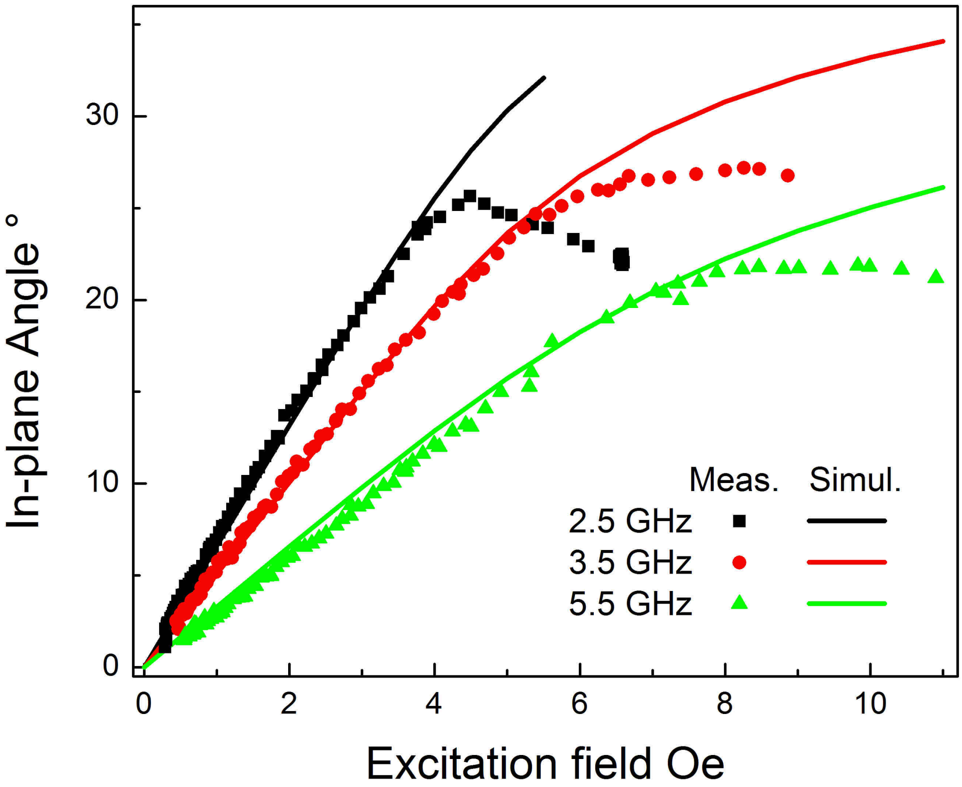

In-plane excitation angle as a function of excitation field for a 20 nm thick Permalloy film measured at 2.5, 3.5, and 5.5 GHz.